MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2016/2017

TIF2721/TSE2351 – INTRODUCTION TO FORMAL METHODS

(All sections / Groups)

27 FEBRUARY 2017
9.00 AM – 11.00 AM
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 5 pages (including the cover page) with 4 Questions only.
2. Answer ALL questions. All questions carry equal marks and the distribution of the marks for each question is given.
3. Please print all your answers in the Answer Booklet provided.

Question 1 (5 + 3 + 3 + 4 marks)

(a). In software engineering, there are mainly two methods for verifying that a piece of software fulfils its functional requirements – *software testing* and *formal proofs of correctness*.

i. Outline two key differences between testing and formal proofs.
ii. When is the use of formal proofs viable?

(b). Suppose that you are eliciting the requirements for a university learning management system. One of the requirements is: "Every student must take exactly one foreign language course". Which of the following correctly expresses this particular requirement? State either Option 1 or Option 2, and give a brief explanation. (The sets of students and foreign language courses are declared in Z notation as [*STUDENTS, FLANG*])

Option 1: $STUDENTS \rightarrow FLANG$
Option 2: $STUDENTS \nrightarrow FLANG$

(c). The domain restriction operator '$\lhd$' on a relation R between two sets X and Y is defined as:

$$\forall S: \mathbb{P}\, X;\ R: X \leftrightarrow Y \bullet$$
$$S \lhd R = \{x : X;\ y : Y \mid x \in S \land xRy \bullet x \mapsto y\}$$

Given the following relation:

$$directory = \{ lincoln \mapsto 2855, chong \mapsto 2860, larry \mapsto 2865, mutu \mapsto 2870\}$$

Find $\{chong, larry\} \lhd directory$

(d). Assume that a colleague of yours made the following statement: "The use of formal methods increases the cost of software development". Present a brief argument against this statement.

Continued...

Question 2 (2 + 13 marks)

(a). Here are some valid Hoare Triples:

$\{x = 5\}\ x := x * 2\ \{true\}$
$\{x = 5\}\ x := x * 2\ \{x > 4\}$
$\{x = 5\}\ x := x * 2\ \{x = 10\}$

Which triple has the strongest post-condition?

(b). Here is a pseudo-code of a program that computes the sum of the numbers stored in an array. The first and last lines in curly braces are the pre-condition and post condition respectively.

$\{ N \geq 0 \}$

$k := 0;$
$m := 0;$

while $(k < N)$ do
  $k := k + 1;$
  $m := m + a[k];$
end

$\{m = (\Sigma_i \mid 0 \leq i < N \bullet a[i])\}$

The invariant is given as $\{0 \leq k \leq N \ \&\& \ m = (\Sigma_i \mid 0 \leq i < k \bullet a[i])\}$.

i. Prove that the invariant is initially true.

ii. Prove that the pseudo-code is incorrect, that is, the array sum that it computes is not correct. (Hint: Attempt to show that the invariant is maintained between the loop iterations).

iii. How do you correct the code so that it computes the array sum correctly?

Continued ...

Question 3 (3 + 3 + 5 + 4 marks)

Assume that you have been given the task of specifying the functional requirements of a system to manage the sales of concert tickets. A typical concert will have a limited number of seats. Answer the following questions:

(a). Specify the state schema of this system in Z. The state schema must contain the following information:
- The set of all seats.
- The seat(s) sold to every customer.

(b). A concert can span several days. There is a requirement that tickets for the first day are only sold to invited friends. Specify this requirement using a Z schema.

(c). Specify an operation called *Purchase*. This operation will take the following as inputs: the seat to be purchased (assume that a customer can only purchase one ticket at a time) and the person making the purchase.

(d). A person will not be able to purchase a ticket if the requested seat is already sold or the person is not an invited friend. Express this requirement in a Z schema called *NotAvailable*.

Continued...

Question 4 (5 + 5 + 5 marks)

(a). The factorial of a number n is defined by the following recurrence relation:

$$n! = \begin{cases} 1 & \text{if } n = 0 \\ (n-1)! \times n & \text{if } n > 0 \end{cases}$$

Specify the factorial function using Z notation.

(b). Using Z notation, specify a function that, given a set of integers, returns the smallest integer. The integers in the set are not necessarily unique.

(c). Using Z notation, specify a function that, given a sequence of items, returns the last element in that sequence.

End of Paper